NOTE

Indian J. Phys. **69A** (6), 645–648 (1995)

IJP A
- an international journal

Efficiency of a Si(Li) X-ray detector with appropriate corrections used for the reaction ^{103}Rh(n,n') ^{103m}Rh

M M H Miah*

Institut für Radiumforschung und Kernphysik, Boltzmanngasse 3, A-1090 Wien, University of Vienna, Vienna, Austria

Received 22 February 1995, accepted 5 July 1995

Abstract : The efficiency of a Si(Li) X-ray detector has been calibrated by means of two standard X-ray point sources ^{109}Cd and ^{93m}Nb with the corrections for extended sources and the self-absorption of KX-rays into the samples. The result obtained for the same is used to measure the activities of the irradiated ^{103m}Rh samples

Keywords : Si(Li) X-ray detector, efficiency, dosimetry reaction

PACS Nos. : 29.30.Kv, 23.20.Nx, 25.40.Fq

The efficiency calibration is of considerable importance in many applications of X-ray spectrometry as, for example in the measurement of cross-section by activation method. Many authors [1–3] measured the cross-sections for the reaction ^{103}Rh(n,n′)^{103m}Rh, by detecting the 20 keV KX-rays emitted by total internal conversion from the irradiated ^{103m}Rh using the particular detector for each experiment. Owing to the fact that the efficiency of the detector is influenced very much by the sample size and the self-absorption of low energy KX-rays into the activated Rh samples, the cross-sections measured by the above authors were not in good agreement with each other as reported in the paper [4]. So, the aim of the present work was to carry out the detection efficiency of the same detector very carefully with necessary corrections and it was then applied specifically to Rh activation.

The KX-rays of irradiated ^{103m}Rh samples were measured by means of a Si(Li) detector (area approx. 201 mm^2) having an energy resolution of 440 eV for 22.61 keV, installed at Physikalisch-Technische Bundesanstalt (PTB), Germany. The efficiency of the said detector was calibrated by using two standard X-ray point sources [^{93m}Nb (average energy 16.92 keV) and ^{109}Cd (average energy 22.61 keV)]. By placing the two sources one

*Permanent address : Department of Physics, University of Chittagong, Chittagong, Bangladesh

by one at the centre of the detector, the ($K_\alpha + K_\beta$) peaks were accumulated for a specific counting time and the summed area of ($K_\alpha + K_\beta$) were analyzed using the IRUK program available at this Institute. From the measured peak count rates and the known photon emission rates, the efficiency for the corresponding sources was calculated.

The efficiency for an extended source :

The efficiency has been studied by placing the same source at a distance of 5 mm at the right, left, front and back position from the centre of the detector. In the same way, the peak area of the sources was calculated and also the efficiency for the corresponding positions. Thus from the well known parabolic shape of the efficiency, its value for an extended source of 5 mm radius averaged over its area was found :

For ^{93m}Nb	0.01510 ± 2.26%
and ^{109}Cd	0.01483 ± 1.50%

It is observed that this variation of efficiency for ^{93m}Nb and ^{109}Cd point sources is 7.53% and 8.34% respectively from their central values. The efficiency for Rh (at an energy of 20.61 keV) was found to be 0.01492 ± 1.80% by linear interpolation from the results obtained by the two point sources.

Correction for self-absorption :

The irradiated Rh samples are 0.0125 cm thick and 10 mm in diameter. These are 'thick' in the sense that a significant fraction of low energy X-rays is self absorbed but 'thin' in geometrical sense. The correction for the KX-ray photons was done theoretically by

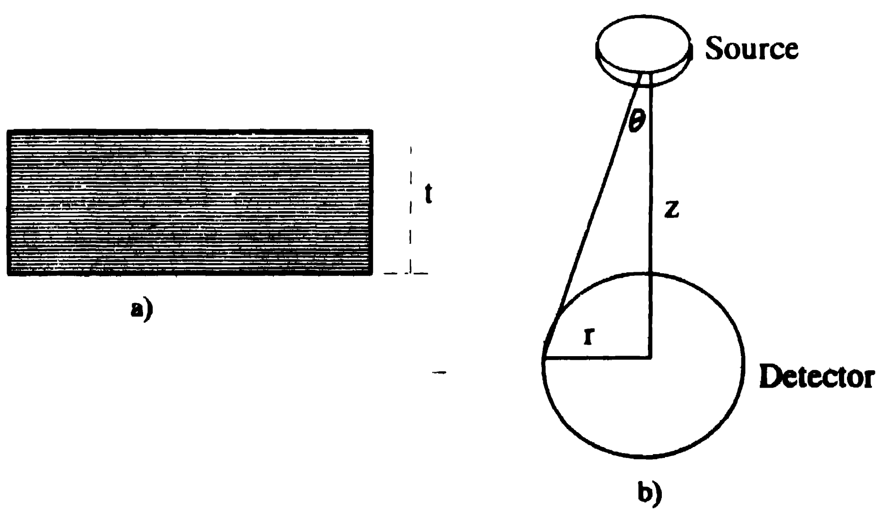

Figure 1. Self-absorption of K X-rays into the irradiated Rh samples :
(a) Sample thickness into layers.
(b) Diagram for the calculation of θ.

dividing the whole thickness into small layers as shown in Figure 1(a) and the formula deduced for the calculation of self absorption over the sample thickness is

$$\frac{1-\exp(-\mu t)}{\mu t} = \frac{1-\exp[-(\mu/\rho)(\rho t)]}{(\mu/\rho)(\rho t)}. \tag{1}$$

The above relation is valid only for small solid angle in which the photons pass almost perpendicular through the absorbing foil. The mass attenuation coefficient μ/ρ was determined in a separate experiment from the count-rates of the sample with and without the inactive foil for the same counting time using the relation

$$I = I_0 \exp(-\mu t) = I_0 \exp[-(\mu/\rho)(\rho t)], \tag{2}$$

where, the symbols represent :

I, I_0 = count-rates of the sample with and without the inactive foil,

t = thickness of the Rh sample,

ρ = density of the Rh sample = 12.5 gm/cm^3.

By inserting the values of all the quantities of eq. (2), the experimental value of μ/ρ was found to be 14.34 ± 1.50% cm^2/g, which is higher in comparison with the theoretically calculated value (13.86 cm^2/g) using the literature [5]. The fact due to this higher value is the variation of the angle of incidence of the photons with the normal of the points between the source and the detector when they are absorbed by the detector as shown in Figure 1(b). Thus, the effective attenuation coefficient in the same equation as above is related by,

$$I = I_0 \exp(-\mu_{\text{eff}} \cdot t) = I_0 \exp(-\mu_{\text{eff}}\, \overline{t\cos\theta}), \tag{3}$$

where $$\mu_{\text{eff}} = \frac{\mu}{\cos\theta}. \tag{4}$$

From Figure 1(b), $$\cos\theta = \frac{z}{\sqrt{z^2+r^2}}. \tag{5}$$

As the source and the detector radius is not negligible compared with their distance of separation (18.50 mm), the calculation for $\overline{\cos\theta}$ over the area of the source and detector was accounted analytically by dividing them into small ring-shaped along their radius by the relation :

$$\overline{\cos\theta} = \frac{\sum_{i=j} \Delta A_1^i \Delta A_2^j \cos\theta_i}{A_1 A_2}. \tag{6}$$

Here, ΔA_1^i and ΔA_2^j is the area of the ring for the source and the detector respectively. This way, the calculated value of $\cos\theta$ is 0.9691, for which μ_{eff} = 14.30 cm^2/g is in good agreement with the experimental value. Thus, taking the experimental value of 14.34 ± 1.50% cm^2/g, the correction for self-absorption for the individual sample was calculated by eq. (1).

Applying the above technique and knowing the reaction rates, the excitation function for the same reaction in the energy range 5.7–12.0 MeV measured by us [6], agrees well with the previous measurement [2]. This has been achieved after the renormalization of all previously measured data with respect to the recent KX-ray emission probability values [6] and the precision measurement for the correction of self-absorption in a different way than used previously. On the contrary, a difference of more than 20% is observed between two measurements [1] and [2] which results a disagreement with the shape of our excitation function. It is important to note that our cross-section data is more reliable and accurate than all other existing data in the stated energy range.

Acknowledgment

The author would like to thank Prof. H Vonach of Institut für Radiumforschung und Kernphysik and Dr. W Mannhart of Physikalisch Technische Bundesanstalt for their valuable suggestions in this work. Thanks are also due to Dr. K Debertin of PTB for providing the necessary X-ray facilities.

References

[1] A Paulsen, R Widera, R Vaninbroukx and H Liskien *Nucl. Sci. Engg.* **76** 331 (1980)

[2] D C Santry and J P Butler *Can. J. Phys.* **52** 1421 (1974)

[3] Wu Zhihua, Wu Songmao, Xu Zhizheng, Song Linggen, You Junsheng, Li Jianwei and Ding Meisong *Proce. of Int. Conf. on Nucl Data for Sci. and Tech.* ed S Igarasi (Tokyo : Saikon) p 315 (1988)

[4] B Strohmaier, S Tagesen and H Vonach *Physics Data* (Fachinformationszentrum, Karlsruhe) Nr. **13-2** (1980)

[5] E Strom and Harvey Israel *Nucl. Data Tables* **Vol. 7 No. 6** 598 (1970)

[6] M M H Miah, H Vonach, W Mannhart and D Smidth *Proce. of Int. Conf. on Nucl. Data for Sci. and Tech.* ed. J K Dickens (Illinois : American Nuclear Society) **Vol. I** p 278 (1994)